Quantum Design electrical transport user training seminar

part 3: interpreting the data

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outline of seminar

- Resistivity option
- AC Transport option
- Electrical Transport Option

- transport applications topics

- subtopics for each option:
  - what is reported in .DAT file?
  - what is actually measured?

Resistivity data file (.DAT)

- resistivity (R*A/L)
  - A/L entered by user when creating new .DAT file
- Excitation
- Std. Dev.
  - sigma from 25 readings
- Number of Readings
- Resistance (R)
- no .RAW data
- no error reporting for:
  - railed current source
  - voltmeter overflow

	Field Name	Field Value
1	Time Stamp (minutes,relative	2.782
2	Status (code)	4881
3	Temperature (K)	4.20024991035461
4	Magnetic Field (Oe)	-0.0949999988079071
5	Sample Position (deg)	0
6	Bridge 2 Resistivity (Ohm)	17509.03875
7	Bridge 2 Excitation (uA)	0.800999999046326
8	Bridge 2 Std. Dev. (Ohm)	1.86902650745856
9	Number of Readings	25
10	Bridge 2 Resistance (Ohms)	17509.03875

Resistivity: what is actually measured?

- voltage from sample
  - converted to resistance R=V/I
- voltage across Vishay resistors
  - used to calibrate current
  - not done in Fast mode

ACT data file

- more diagnostics here
  - harmonics
  - quad. error
  - ACT status
  - ACT gain
- see app note 1084-403

	Field Name	Field Value
1	Time Stamp (minutes,relative	0.345
2	Status (code)	4369
3	Temperature (K)	299.99695
4	Magnetic Field (Oe)	0
5	Excitation (mA)	10.3445784652368
6	Frequency (Hz)	100
7	Volts ch2	0.206970494356627
8	V Std.Dev. ch2	1.39597931637484E-5
9	Res. ch2 (ohm-cm)	20.0080414418348
10	Res. Std.Dev. ch2	0.00134949919699346
11	ACT Status (code)	0
12	ACT Gain	10
13	2nd Harm. ch2 (dB)	-90.5550939126767
14	3rd Harm. ch2 (dB)	-88.1096826882046
15	Quad.Error ch2 (ohm-cm-rad	0.000118352628304117
16	Drive Signal ch2 (V)	0.206971683096952

ACT: what is actually measured?

- voltage from sample
  - for I-V and c.c., the accumulated d.c. voltage reported
  - all others, a.c. component from lock-in calculation
- source current NOT measured
  - very stable current source
    - source compliance errors are reported to user
  - unless “Constant Current Mode” turned off!!
    - see ACT app. note 1084-402

ETO data file

- similar to ACT but ETO does much more
  - both 2- and 4-wire modes
  - dV/dI mode
- categories of data
  - BASE SYSTEM
  - ETO universal basics
  - I-V (4- or 2-wire)
  - 4-wire Resistance and dV/dI
  - **2-wire Resistance and dI/dV**
  - peripheral info

Comment
Time Stamp (sec)
Temperature (K)
Field (Oe)
Sample Position (deg)
Pressure (Torr)
Resistance Ch1 (Ohms)
Resistance Std. Dev. Ch1 (Ohms)
Phase Angle Ch1 (deg)
I-V Current Ch1 (mA)
I-V Voltage Ch1 (V)
Frequency Ch1 (Hz)
AC Current Ch1 (mA)
DC Current Ch1 (mA)
Averaging Time Ch1 (sec)
Voltage Ampl. Ch1 (V)
In Phase Voltage Ch1 (V)
Quadrature Voltage Ch1 (V)
AC Voltage Ch1 (V)
DC Voltage Ch1 (V)
Currrent Ampl. Ch1 (mA
Current Std. Dev. Ch1 (mA)
In Phase Current Ch1 (mA)
Quadrature Current Ch1 (mA)
Gain Ch1
ETO Status Code
ETO Measurement Mode
2nd Harmonic Ch1 (dB)
3rd Harmonic Ch1 (dB)

ETO: what is actually measured?

- similar philosophy with ACT:
  - 4-wire mode: only voltage measured
    - source current assumed stable
  - 2-wire mode: only current measured
    - source voltage assumed stable
  - source compliance errors are reported
- in I-V dialog, “Disable Drive Feedback” is like turning off constant current mode in ACT
  - in ETO, however, we DO correct the current

transport applications topics

***** - indicates there is an app note on this topic

- **all options:** common mode leakthrough in longitudinal resistance measurements *****
  - symptom: noticed more in low R measurements, leads to false shift (+ or -) in reported resistance (“negative resistance”)
  - avoid unsymmetric placement of sample voltage leads relative to current leads
  - avoid contact resistance at I+ or I- lead: biases sample voltage
- **all options:** non-ohmic contacts; some common symptoms:
  - R being dependent on drive current
  - I-V (scan excitation) clearly shows nonlinearity
  - in .RAW file V(t) is not sinusoidal (high Res.Std.Dev. in .DAT)
  - negative reported resistance

tranport applications topics, part 2

- **ACT:** balance of 5-wire Hall
  - still need to measure R(B) at +/- fields as some imbalance will remain
    - ½ [R(+B) – R(-B)] = Rxy
    - ½ [R(+B) + R(-B)] = Rxx
    - sample magnetic state must be identical in R(+B) and R(-B)
  - rotator convenient for this method: measure at 0 and 180 degrees
  - imbalance effects are less significant in $R_H=\rho_{xy}/B$ at high fields
  - may need rebalancing at new temperature
  - see Appendix C of ACT User Manual
- **ACT/ETO:** Inconel feedthrough and a.c. signal distortion in region T = 25-35 K *
  - minimize by choosing low drive frequency

transport applications topics, part 3

- **ACT:** choose appropriate AC frequency for measurement
  - avoid line frequency and harmonics: 17 Hz, 103 Hz...
  - (ETO gives user a short list of recommended freq's)
- **ACT:** record .RAW data, shows V(time) traces
  - diagnoses interference, contact problems, hardware problems
- **ETO:** use low freq. on high resistance (R) samples
  - relevant only to 4-wire measurements
  - phase shift due to capacitance of leads (C~375 pF)
  - in resistance and I-V, choose f so that $f << (RC)^{-1}$
    - e.g. f = 0.3 Hz for I-V curve on R=1 MΩ sample